Entropy scaling from chaotically produced particles in p-p collisions at LHC energies

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Abstract

Scaling of information entropy obtained from chaotically produced particles in p-p collisions, has been shown to be valid up to the highest available collision energy at LHC. Results from Monte Carlo simulation model PYTHIA 6.135 have also been compared. Based on the two component model and collision energy dependence of the chaoticity, charged particle multiplicities at proposed higher collision energies have been predicted.

Key words: hadronic collisions, multiparticle, chaoticity, entropy, scaling, LHC
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1. Introduction

Multiparticle production in high energy hadron-hadron, hadron-nucleus and nucleus-nucleus collisions has been in the center of interest in the field of experimental high energy physics programs for the last four decades. But in spite of this rigorous exercises for such a long period, no satisfactory as well as consistent theory has emerged to explain the results from these studies. Although the quantum chromodynamics (QCD) has been accepted as the proper theory for the strong interaction envisaged in these collisions, it is still not known how to treat the soft, thus non-perturbative processes. Moreover, the investigations of the equation of state of the matter produced in these collisions has become a matter of increased interest because of its connection with the studies on Quark Gluon Plasma [1,2]. Trace of deconfinement in hadronic collisions at TeV energies have already been reported earlier [3]. Recently very high multiplicities and other new features have become the central matter of discussions after the data from LHC have come out [4,5]. Considering these facts, one could say that the experimental data in this particular

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field are more important than any other. Analyses of these data using statistical moments [6,7] and scaling laws provide new ideas to interpret the results. At the beginning of this exercise, Bjorken scaling was accepted to be the tool to explain the picture of parton degrees of freedom. The collision energy dependence of the multiplicity of the produced particles was nicely explained by KNO scaling [8] up to the ISR energies. But this scaling law broke down [6,7] once the collision energy increased. A new quantity, entropy [9], was proposed to revive the scaling of multiplicity distributions in high energy hadronic collisions at the collider energies. However, the new scaling holds good for the entire range of energy starting from ISR ($\sqrt{s}$ = 19 GeV) up to the highest available collision energy at SPS ($\sqrt{s}$ = 900 GeV) only if the entropy is calculated from the chaotically produced particles [10]. In this paper we will discuss the results from this scaling law for the multiplicity distributions for p-p collisions at the available collision energies at LHC.

2. Formalism

The scaling variable, *information entropy*, has been calculated within the context of the two component model [11] for multiplicity distribution. According to this model the emission of particles occurs from a convolution of a chaotic source with $k = 1$ or 2 and a coherent one mode source. The entropy for multiplicities in symmetric pseudorapidity intervals $|\eta| \leq \eta_c$ is given by

$$\begin{aligned} S(\eta_c, \sqrt{s}) = {} & (n_{ch}(\eta_c, \sqrt{s}) + 1) ln(n_{ch}(\eta_c, \sqrt{s}) + 1) \\ & - n_{ch}(\eta_c, \sqrt{s}) ln n_{ch}(\eta_c, \sqrt{s}) \end{aligned} \quad (1)$$

where n_{ch} is the chaotic fraction of the average multiplicity. This is obtained from the total multiplicity by

$$n_{ch} = \tilde{P} n \quad (2)$$

where

$$\tilde{P} = [k\{C_2 - (1 + 1/\langle n \rangle)\}]^{1/2} \quad (3)$$

and $C_2 = \langle n^2 \rangle / \langle n \rangle^2$, the second moment of multiplicity distribution and $\langle n \rangle$ is the mean of the distribution. Then we plot S/η_{max} as a function of $\xi = \eta_c/\eta_{max}$ where

$$\eta_{max} = ln[(\sqrt{s} - 2m_n)/m_\pi] \quad (4)$$

3. Results

In Fig. 1 the S/η_{max} has been plotted as a function of η_c/η_{max} for different collision energies starting from SPS [6,7] up to the highest available energy at LHC [12]. This figure shows that the results from of all different collision energies fall on a single curve within the estimated statistical errors. We have also plotted the results obtained from Monte Carlo simulation program PYTHIA 8.135 [13] for the same energies as well as the projected highest collision energy at LHC ($\sqrt{s}$ = 14 TeV). PYTHIA shows slight differences at higher pseudorapidities.

After the new scaling has been established, we have plotted the mean multiplicity of chaotically produced particles (n_{ch}) as a function of collision energy for different values

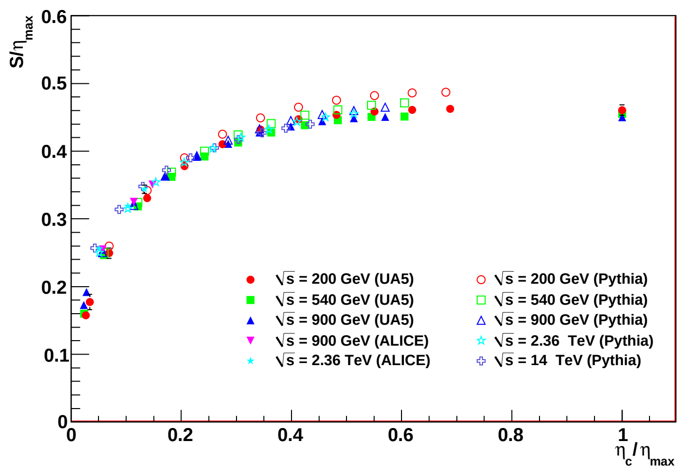

Fig. 1. Entropy scaling from two component model. Results from data and simulation have been shown with "solid" and "open" symbols respectively.

of ξ (Fig. 2). Here we have plotted this quantity for three different ξ values for which data are available from ALICE experiment. Fitting this distribution with a power law, one obtains the n_{ch} at higher collision energies that will be obtained at LHC in near future. We have also plotted the other fraction of multiplicity *i.e.* the multiplicity of coherently produced particles as a function of collision energy in the similar way. This quantity shows a non monotonous behaviour as the energy increases beyond 1 TeV. This tells us that beyond this point the chaotic fraction of multiplicity predominates. At collision energy 14 TeV the chaoticity parameter $\tilde{P}$ reaches very close to unity.

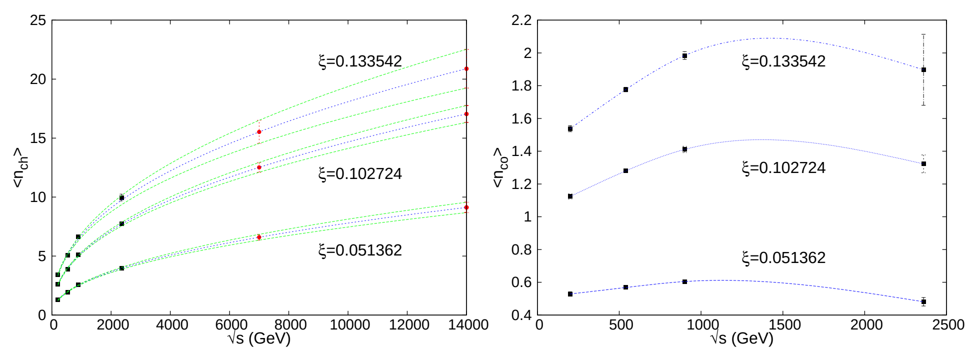

Fig. 2. Mean chaotic multiplicity, n_{ch} (left) and mean coherent multiplicity n_{co}(right), as a function of collision energy. The black (square) and red (circle) points correspond to data and predicted points respectively and the green bands show the limits of statistical errors. The lines in the right plot are to guide the eye.

We understand that the more important quantity from experimental point of view is the average of total multiplicity as that could be measured directly in the experiments. Keeping this in mind we have finally plotted that quantity again as a function of energy for available collision energies and fitted that distribution again with a power law. From the fitting we predict the average multiplicity in p-p collisions at 7 TeV and 14 TeV

collision energies and most central pseudorapidity bin to be 6.678 ± 0.242 and 8.658 ± 0.404 respectively.

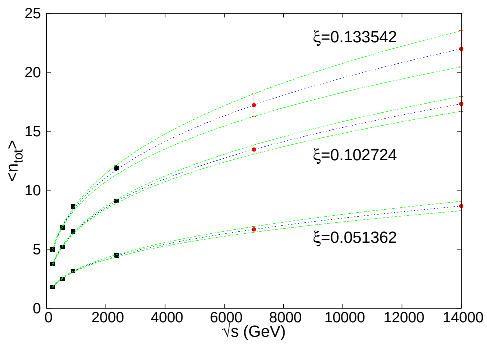

Fig. 3. Mean total multiplicity, n_{tot}, as a function of collision energy. The black (square) and red (circle) points correspond to data and predicted points respectively.

4. Summary

In summary we have applied the two source model to extract the multiplicity of the chaotically produced charged particles at the LHC energies. The information entropy obtained from this scales nicely up to the highest available collision energy at LHC. The chaoticity parameter obtained at LHC energies is close to unity signifying the possibility of collective phenomena in hadronic collisions at these energies. We have gone further to predict the multiplicities for the proposed higher energy collisions at LHC.

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